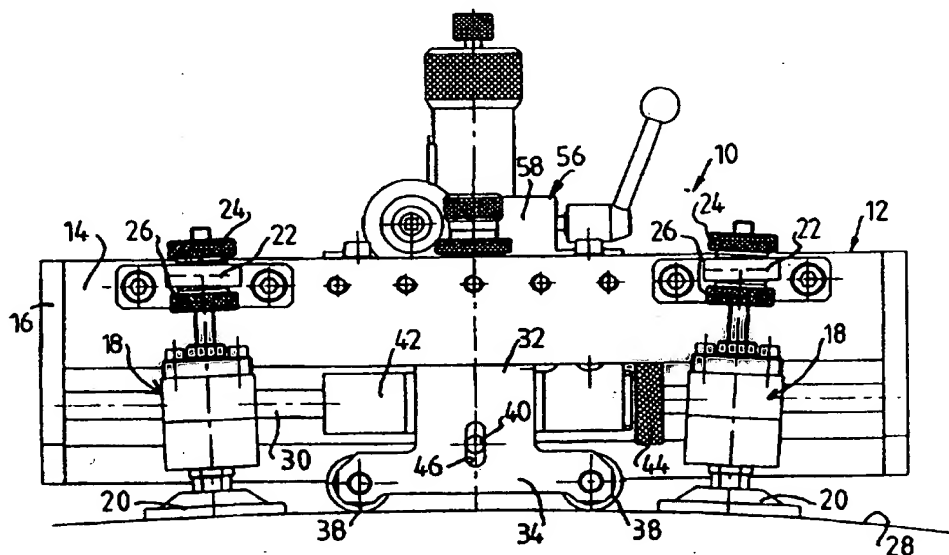




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification <sup>6</sup> : <b>B64B 5/00, B23K 7/10, B23Q 1/62</b></p>	<p>A1</p>	<p>(11) International Publication Number: <b>WO 97/29953</b></p> <p>(43) International Publication Date: <b>21 August 1997 (21.08.97)</b></p>
<p>(21) International Application Number: <b>PCT/SE97/00164</b></p> <p>(22) International Filing Date: <b>4 February 1997 (04.02.97)</b></p> <p>(30) Priority Data: <b>9600573-1 16 February 1996 (16.02.96) SE</b></p> <p>(71) Applicant (for all designated States except US): <b>NOVATOR AB [SE/SE]; Björnåsvägen 21, S-113 47 Stockholm (SE).</b></p> <p>(72) Inventor; and (75) Inventor/Applicant (for US only): <b>LINDERHOLM, Dag [SE/SE]; Rönninge Skolväg 42, S-144 62 Rönninge (SE).</b></p> <p>(74) Agent: <b>WINBLAD, Peter; H. Albihs Patentbyrå AB, P.O. Box 3137, S-103 62 Stockholm (SE).</b></p>		<p>(81) Designated States: <b>AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</b></p> <p><b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments. In English translation (filed in Swedish).</i></p>

(54) Title: **EQUIPMENT FOR CUTTING A HOLE OR CAVITY FORMATION IN A CURVED OR FLAT WALL ELEMENT AND FOR CUTTING OUT A DISC-SHAPED PIECE OF MATERIAL FITTING THE HOLE OR CAVITY FORMATION**



## (57) Abstract

The invention relates to equipment for making a hole or cavity formation in a curved or planar wall element and for cutting out a disc-shaped piece of material fitting the hole or cavity formation. The equipment (10) comprises a frame (12) with means (18, 20) for fixing it on the wall element, and a carriage (32) displaceably mounted in a first linear direction. A slide (56) is mounted to be displaceable perpendicular to the first linear direction and carries a tool unit (60). The carriage (32) has wheel sets (34), which are biased against the wall element, the wheel sets (34) being pivotable and displaceably mounted on a respective guide slide (42), which is mounted to be displaceable in said first linear direction.

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**Equipment for cutting a hole or cavity formation in a curved or flat wall element and for cutting out a disc-shaped piece of material fitting the hole or cavity formation**

5 The present invention relates in general to equipment for cutting a hole or cavity formation in a curved or flat wall element, and relates primarily, but not exclusively, to preferably portable equipment for cutting a hole or cavity formation in a curved, relatively thin-walled element.

10 It has previously been quite difficult, if at all possible, to perform, with great precision, reliable repairs of damage to shell structures having a curved surface, especially in the field. This is, for example, the case when damage has occurred to a wing or a fuselage of an airplane. Due to the fact that the outer wall of the structural components of the airplane are often curved along a single axis and can consist of  
15 composite material, special requirements are placed on the precision and geometry, not only in making a new larger hole or cavity about the damage but also when making new disc-shaped pieces of material which must fit precisely into the cut-out hole or cavity.

20 One purpose of the present invention is to suggest equipment which makes possible cutting of a well-defined hole or cavity formation in a curved wall element, where the hole is of arbitrary configuration and a suitable joint arrangement, for example, a step joint with the desired geometry. The equipment according to the invention must also make possible creating a plurality of screw or rivet holes in a desired  
25 closely spaced hole distribution around wall damage and creating a corresponding hole distribution around a disc-shaped repair patch, intended to overlap the damage, without the aid of special templates or drill bushings.

30 For this purpose, the equipment described by way of introduction is characterized according to the invention in that it comprises a frame with means mounted thereon for fixing the frame to the wall element; first rectilinear, parallel guide means fixed

in the frame for guiding a respective support means of a carriage displaceably mounted in the frame in a first linear direction, said support means having slide or roller elements intended to be in contact with the surface of the wall element and facilitate the movement of the carriage thereon in the first linear direction; second  
5 rectilinear, parallel guide means connecting respective support means to each other; a slide which is displaceably mounted on the second guide means in a second linear direction substantially perpendicular to the first linear direction, said slide being disposed to carry a tool unit for cutting a hole or cavity formation in the wall element; a guide slide which is displaceably mounted on cooperating first guide  
10 means and is joined to a respective support means in such a manner that the support means is, firstly, pivotally mounted relative to the guide slide about a pivot axis parallel to said second guide means, and, secondly, is displaceably mounted relative to the guide slide in a direction normal to the surface of the wall element against which the slide or roller element of the support means are intended to be in contact;  
15 and means arranged to bias each support means with its slide or roller element against the surface of the wall element. Such an arrangement makes it possible to anchor the frame in such a manner over the damage to the wall element that the carriage and the tool unit carried thereon can be made to follow the curvature of the wall element with the operating axis of the tool unit always oriented perpendicular  
20 to the surface of the curved wall element.

In order to facilitate guiding and limiting the movement of the tool unit over the wall element, the frame is suitably arranged to support a template having a cam surface with a profile corresponding to the perimeter of the hole or cavity which is  
25 to be cut into the wall element. The slide, or the tool unit carried thereon, has a component in the form of a cam follower designed to move in contact with the cam surface.

The equipment is preferably so dimensioned and designed so as to be portable and  
30 is suitable for use in the field. The carriage and the slide with the tool unit mounted thereon can thus be manually operated for cutting the hole or cavity, with the cam

5 follower in contact with the cam surface of the template. By virtue of the fact that the frame can be fixed to the wall element in any plane orientation, the operator does not need to carry any portion of the weight of the equipment when it is used. The equipment permits working close to edges and impediments, e.g. mountings on an airplane wing.

10 According to another aspect of the invention, the above described equipment, possibly with certain components modified or excluded, can also be used for cutting disc-shaped pieces of material (repair patches), the peripheral shape of which exactly corresponding to that of the hole or cavity in the wall element, as well as repair patches, which are to overlap a damaged section and be fixed in place with screws or rivets onto the damaged wall element. The frame itself need to have its fixing means mounted on a surface having essentially the same curvature profile as the wall element where the hole or cavity has been cut out. Rather, it is only necessary  
15 in this case that the carriage with its support means be arranged to run on such a corresponding profile surface, which can suitably also form the subsurface for the sheet of material from which the disc is to be cut. The frame can be placed in an underframe which is in turn supported on a solid subsurface. The tool unit used consists in this case of a cutting unit, such as a cutting wheel, a laser knife, a water  
20 jet nozzle or the like.

Other features of the equipment according to the invention are disclosed in the accompanying dependent claims.

25 The invention will be described in more detail below with reference to the accompanying drawings, in which:

Figure 1 is a side view of equipment according to the present invention, fixed on a curved surface;

30 Figure 2 is a plan view of the equipment in Fig. 1;

Figure 3 is a sectioned side view of a wheel set for a carriage linearly movable in the frame and biased against the subsurface;

Figure 4 is an end view of a portion of the equipment according to the invention where a tool unit cooperates with a cam surface of a hole-cutting template;

Figure 5 is a plan view of a hole-cutting template in the form of a leaf diaphragm;

Figure 6 is a plan view of equipment according to the invention in which intersecting ruler elements are used to form a hole-cutting template; and

Figure 7 shows an embodiment of the equipment according to the invention, where a positional indicator is coordinated with the carriage and a slide displaceable transverse thereto.

With reference to the drawings and in particular Figs. 1 and 2, equipment generally designated 10 is shown, which makes possible simple and precise cutting of a hole or cavity formation in an underlying single-curved or flat piece of material. The equipment is primarily, but not exclusively, intended to be used in the field for repairing damage to wall elements of shell structures, e.g. single-curved wall elements, such as surface sections of wings or parts of airplanes. Such wall elements in modern airplanes are often single-curved and can consist of composite material, which

places special tolerance requirements on both cutting of new holes or cavities around an existing damaged area and cutting of one or more new pieces of material which must fit exactly and be fixed in the hole or cavity. The equipment 10 suggested according to the invention makes possible such a simplified exact cutting of holes and cutting of new pieces of material to fit therein.

The equipment 10 consists in principle of a frame 12 which has the shape of a rectangular frame 12 with opposite pairs of lateral frame beams 14 and 16 respectively. In each of the lateral frame beams 12 there are adjustably mounted a pair of frame-fixing means 18 having suction cups 20, each means 18 being supported in a respective holder 22, which is releasably fixable and movable laterally. The means 18 can be fixed in said holder 22 by means of locking means 24, 26 so that the longitudinal axis of the means 18 is kept oriented essentially normal to the curved (or planar) surface 28 on which the frame 12 is to be fixed over an existing damaged area or where a hole or cavity is to be cut for some other reason.

At the end portions of the lateral frame beams 16 there are fixed a pair of first parallel guide means in the form of guides 30 for linear guiding of a carriage 32. The carriage 32 comprises wheel sets 34 cooperating with individual guides 30. The wheel sets 34 are joined to each other by means of a pair of second parallel guides 36 oriented perpendicular to the first guides 30.

Each wheel set 34 has a pair of rollers or wheels 38 spaced in the direction of movement of the carriage 32, in contact with the surface 28 of the wall element in which a hole or cavity is to be cut. As can be seen in Fig. 3, the wheel set 34 is pivotally mounted via a pin 40 in a guide slide 42 which is displaceably guided on the guide 30 and can be locked thereto by means of a lock knob 44. The wheel set 34 is also limitedly displaceably mounted relative to the guide slide 42, perpendicular to the surface 28 on which the wheels 38 roll by virtue of the fact that the pin 40 fixed in the slide 42 is displaceably guided in a slot 46 (Fig. 1) in the wheel set 34.

In order to keep the wheels 38 of the wheel sets 34 in contact with the surface 28, regardless of whether the frame 12 is fixed above a surface as shown in Fig. 1 or is fixed suspended on the underside of a surface to be cut, the wheel set 34 is kept pressed against the surface 28 by means of a tensile spring 48, which is fixed at 50 centrally between the pin 40 in the guide slide 42 and an adjustable anchoring element 52 in the upper portion of the wheel set 34. The guide slides 42 on the guides 30 are joined to each other by means of a transverse rod 54 (Figs. 3 and 4).

A slide 56 is displaceably mounted on the transverse second guides 35. A holder 58 is arranged on a slide 56 to vertically fix a schematically indicated tool unit 60 supporting a tool 62, e.g. a chip-cutting tool, a high-pressure nozzle, a laser implement or the like, for the desired cutting of the wall element on which the frame 12 is mounted. The slide 56, like the wheel sets 34, can be locked to its guides 36 by means of a lock knob 63 (Figs. 2 and 4). The tool unit 60 can, for example, comprise a high-speed pneumatic turbine motor when using chip-cutting tools.

The frame 12 also supports a template or stencil 64, which forms a cam surface 66 for guiding a cam follower 68 on the tool unit 60. When circular holes or cavities are to be cut in the wall element, it is suitable to use a template in the form of pivoting diaphragm leaves 70 (Fig. 5) arranged in the form of a ring. The diameter of the central hole 72 of the diaphragm can be varied by pivoting the leaves 70 with the aid of an operating pin 74 via a pivot mechanism (not shown).

If the holes or cavities are to have another peripheral shape, e.g. a square or triangle, instead of the diaphragm leaves 70 a system of intersecting rulers 76, 78 can be used, which are displaceable and pivotable on a pair of guide rods 80 and 82, respectively, as shown in Fig. 6.

As can be seen in Fig. 7, positional indicators 84 and 86, respectively, can be coupled to the carriage 32 and the slide 56, respectively, to provide the positional



coordinates for the tool 62, especially in those cases where a plurality of screw or rivet holes are to be made in a wall element and where corresponding holes are to be made in a disc-shaped piece of material, which is to provisionally cover a damaged area on the wall element. Since it is difficult to achieve sharp edges in the composite material often used in modern aircraft for making screw holes or rivet holes, a cutting technique is required where the cutting tool rotating about its central axis is at the same time subjected to an oscillating or circular movement about another axis, to provide low cutting forces, good quality of the hole and ease of chip removal.

- 10 A dust and chip vacuum means, the outside of which is suitably formed by the above mentioned cam follower 68, can be co-ordinated with the tool unit 60. This assures good chip removal when cutting holes and cavities.

- 15 The above described equipment can, as mentioned in the preamble to the description and as will be evident from the attached claims 16-26, also be used to cut out pieces of material, the peripheries of which precisely corresponding to the holes or cavities cut into the wall element by means of the described equipment. For this purpose it is required that the material, from which the pieces are to be cut, be placed on a substrate which is preferably made with a profile surface corresponding to that of the cut hole or cavity. The material can be a sheet or web of material fixed to the supporting surface. The wheel set 34 of the carriage 32 must then be able to run on the profiled supporting surface. The fixing means 18 not necessarily need to be anchored on the profiled supporting surface. Rather, they can rest on an adjacent flat supporting surface, or, alternatively, not be used at all, if the frame 12 is coupled to another frame set up on the supporting surface at the cutting location. The tool unit has in this case a cutting tool, e.g. a cutting wheel, a water jet nozzle or a laser knife.

- 25  
30 The equipment 10 according to the invention is designed to be used in the following manner for cutting holes or cavities.

For repairing in the field, for example, a damaged portion of a single-curved wall portion of an airplane wing, the frame 12 is centered over the damaged portion and is fixed in place by means of the fixing means 18 and the suction cups 20. The cam follower 68 of the tool unit 60 is brought into contact with the cam surface 66 of the template 64, and the tool 62 of the tool unit 60 is then brought to the desired cutting depth. The slide 56 can then be manually moved along the cam surface 66 of the template 64, to cut a circular hole, for example. Preferably, the hole is cut in such a manner that a step-shaped hole edge surface is formed, which provides a stronger joint. Alternatively, a provisional repair with an overlapping patch can be used with a plurality of small holes for rivets or screws.

The equipment 10 can then, as described above, be used to cut, in a corresponding manner, one or more disc-shaped complementary pieces of material which precisely fit the hole or cavity in the wall of the wing. For composite material, a plurality of thin pieces of material are suitably cut out which are then glued together or otherwise assembled to form an integrated piece of material for placement and fixing in the hole cut. For provisional repair with an overlapping repair patch, rivet or screw holes are cut therein corresponding to the holes in the wall element, with the aid of the positional indicators 84, 86.

Within the scope of the invention it is also possible to use the equipment for repairing all types of curved glass or plastic sheets or panes. For example, it is possible to repair airplane windshields and cockpits.

## Claims

1. Equipment (10) for cutting a hole or cavity in a curved or planar wall element, characterized by
- 5 a) a frame (12) with means (18,20) mounted thereon for fixing the frame (12) to the wall element;
- b) first rectilinear, parallel guide means (30) fixed in the frame (12) for guiding a respective support means (34) of a carriage (32) displaceably mounted in the frame in a first linear direction, said support means (34) having slide or roller
- 10 elements (38) intended to be in contact with the surface (28) of the wall element and facilitate the movement of the carriage (32) thereon in the first linear direction;
- c) second rectilinear, parallel guide means (36) connecting the respective support means (34) to each other;
- 15 d) a slide (56) which is displaceably mounted on the second guide means (36) in a second linear direction substantially perpendicular to the first linear direction, said slide (56) being disposed to carry a tool unit (60) for cutting a hole or cavity formation in the wall element;
- e) a guide slide (42) which is displaceably mounted on cooperating first guide
- 20 means (30) and is joined to a respective support means (34) in such a manner that the support means is, firstly, pivotally mounted relative to the guide slide (42) about a pivot axis (40) parallel to said second guide means (36), and, secondly, is displaceably mounted relative to the guide slide (42) in a direction normal to the surface (28) of the wall element against which the slide or roller
- 25 elements (38) of the support means are intended to be in contact; and
- f) a means (48) arranged to bias each support means (34) with its slide or roller element (38) against the surface (28) of the wall element.
2. Equipment according to Claim 1, characterized in that the frame (12) is arranged
- 30 to support a template (64) which has a cam surface (66) with a profile corresponding

to the peripheral configuration of the hole or cavity to be cut in the wall element, said slide (56) or the tool unit (60) carried thereon having a portion in the form of a cam follower (68) designed to be in contact with the cam surface (66).

- 5      3. Equipment according to Claim 2, **characterized** in that the cam surface (66) of the template (64) is formed by a ring of pivotable diaphragm leaves (70).
- 10      4. Equipment according to Claim 2, **characterized** in that the cam surfaces of the template (64) are formed by adjustable intersecting ruler elements (76,78).
- 15      5. Equipment according to one of Claims 1 - 4, **characterized** in that at least one of the support means (34) supports wheels or rollers (38) spaced in the direction of movement of the carriage.
- 20      6. Equipment according to one of Claims 1 - 5, **characterized** in that the support means (34) are pivotable and limitedly displaceably mounted on their respective guide slide (42) via a pin and slot mechanism (40,46).
- 25      7. Equipment according to one of Claims 1 - 6, **characterized** in that the biasing means (48) consists of a spring element acting between the guide slide (42) and the support means (34).
8. Equipment according to Claim 7, **characterized** in that the spring element (48) is a tensile spring fixed centrally between the guide slide (42) and the support means (34).
9. Equipment according to Claim 8, **characterized** in that the tension in the tensile spring element (48) can be set by means of a means (52) for moving the anchoring point (50) of the spring element in the support means (34).

10. Equipment according to one of Claims 1 - 9, **characterized** in that the means for  
~~fixing the frame on the wall element comprises suction cups (20).~~

5 11. Equipment according to one of Claims 1 - 10, **characterized** in that the means  
(18, 20) for fixing the frame (12) on the wall element are pivotally fixed to the  
frame (12).

12. Equipment according to one of Claims 1 - 11, **characterized** in that means (84,  
86) for indicating the positional coordinates of the tool unit are coordinated with the  
10 carriage (32) and the slide (56).

13. Equipment according to one of Claims 1 - 12, **characterized** in that a means  
(44 and 63 resp.) is coordinated with at least one of the support means (34) and with  
the slide (56) for locking the carriage (32) and the slide (56), respectively, to their  
15 respective guide means (30 and 36 resp.).

14. Equipment according to one of Claims 1 - 13, **characterized** in that the tool unit  
(60) comprises a chip-cutting tool (62).

20 15. Equipment according to Claim 14, **characterized** in that the tool unit is  
arranged to rotate the tool about its center axis and at the same time rotate the center  
axis in a circular movement about another axis essentially parallel to the center axis.

25 16. Equipment (10) for cutting out a disc-shaped piece of material from a web of  
material or a sheet of material, **characterized** by

- a) a frame (12) arranged to be fixed on a solid supporting surface;
- b) first rectilinear, parallel guide means (30), fixed in the frame (12) for guiding  
a respective supporting means (34) of a carriage (32) displaceably mounted in  
the frame in a first linear direction, said supporting means (34) having slide or

roller elements (38) intended to be in contact with a profile surface and facilitate the movement of the carriage (32) thereon in a first linear direction;

c) second rectilinear, parallel guide means (36) joining together the respective support means (34);

5 d) a slide (56), which is mounted on the second guide means (36) to be displaceable in a second linear direction substantially perpendicular to the first linear direction, said slide (56) being arranged to carry a tool unit (60) for cutting out a disc-shaped piece of material from the web of material or the sheet of material;

10 e) a guide slide (42), which is displaceably mounted on a cooperating first guide means (30) and joined to a respective support means (34) in such a way that the support means is firstly pivotally mounted relative to the guide slide (42) about an axis (40) parallel to the second guide means (36), and secondly is displaceably mounted relative to the guide slide (42) in a direction normal to the profile surface against which the slide or roller elements (38) of the support means are  
15 intended to be in contact; and

f) means (48) arranged to tension each support means (34) with its slide or roller elements (38) against the profile surface.

20 17. Equipment according to Claim 16, **characterized** in that the frame (12) is arranged to carry a template (64), which has a cam surface (66) with a profile corresponding to the peripheral configuration of the piece of material which is to be cut out of the material web or the material sheet, the slide (56) or the tool unit (60) carried thereon having a portion in the form of a cam follower intended to be in contact with the cam surface (66).

25 18. Equipment according to Claim 17, **characterized** in that the cam surface (66) of the template (64) is formed of diaphragm leaves (70) pivotable in a ring.

30 19. Equipment according to Claim 17, **characterized** in that the cam surfaces of the template (64) are formed of adjustable, intersecting ruler elements (76,78).

20. Equipment according to one of Claims 16 - 19, **characterized** in that at least one of the support means (34) supports wheels or rollers (38) spaced in the direction of movement of the carriage (32).

5 21. Equipment according to one of Claims 16 - 20, **characterized** in that the support means (34) are pivotally and limitedly displaceably mounted on the respective guide slide (42) via a pin and slot mechanism (40, 46).

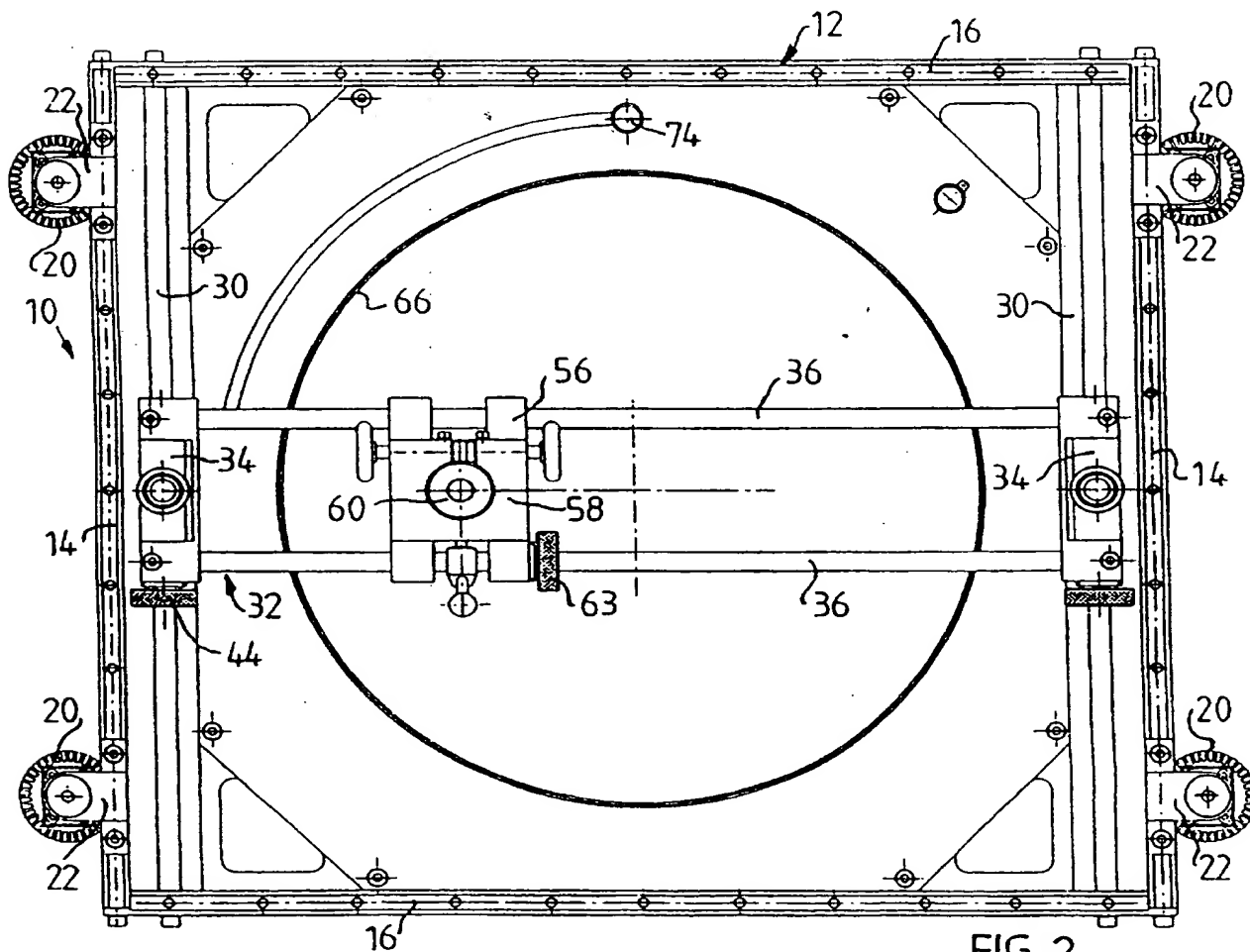
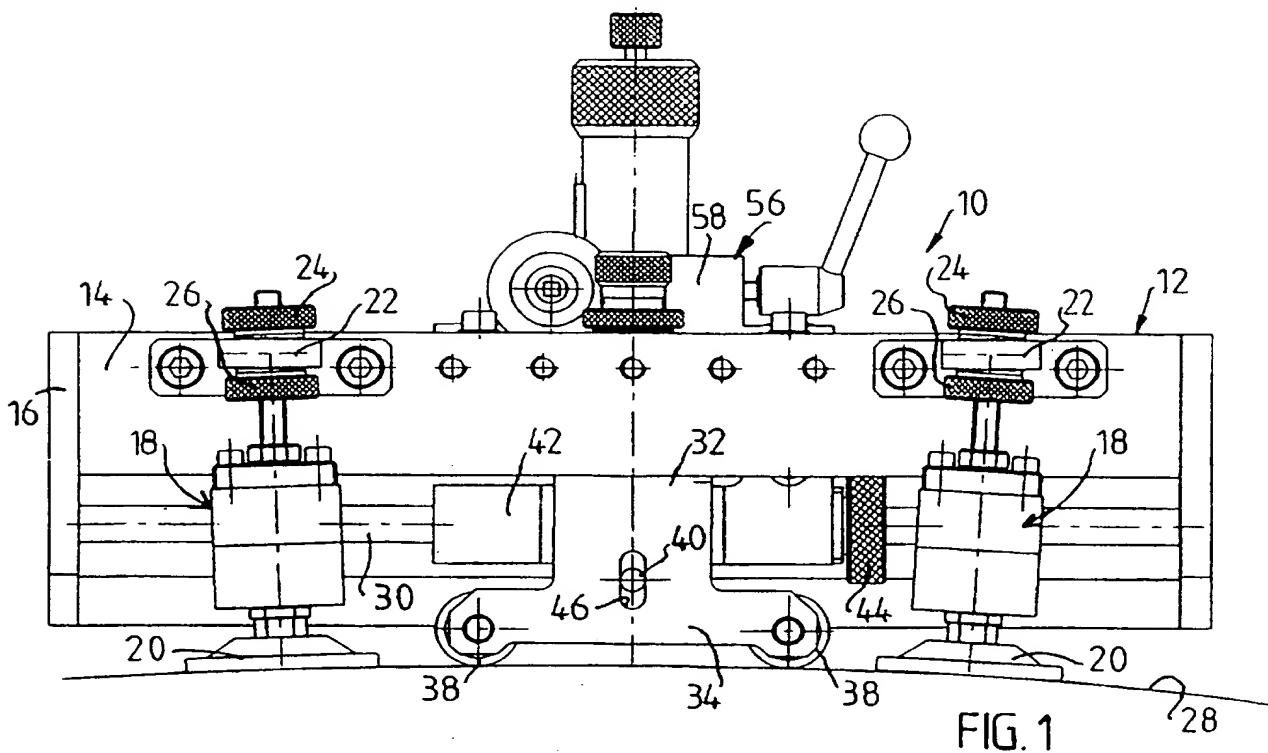
10 22. Equipment according to one of Claims 16 - 21, **characterized** in that the biasing means (48) consists of a spring element acting between the guide slide (42) and the support means (34).

15 23. Equipment according to Claim 22, **characterized** in that the spring element (48) is a tensile spring fixed centrally between the guide slide (42) and the support means (34).

20 24. Equipment according to Claim 23, **characterized** in that the tension in the tensile spring element (48) can be adjusted by a means (52) for moving the anchoring point (50) of the spring element in the support means (34).

25 25. Equipment according to one of Claims 16 - 24, **characterized** in that the tool unit comprises a cutting tool, such as a cutting wheel, a laser knife, a water jet nozzle or the like.

26. Equipment according to one of Claims 16 - 25, **characterized** in that the supporting surface and the profile surface are identical.





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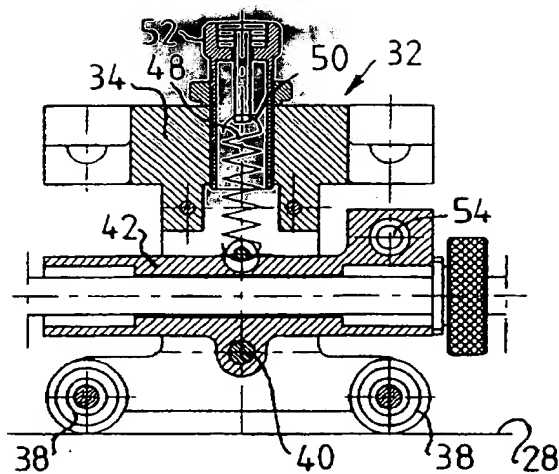


FIG. 3

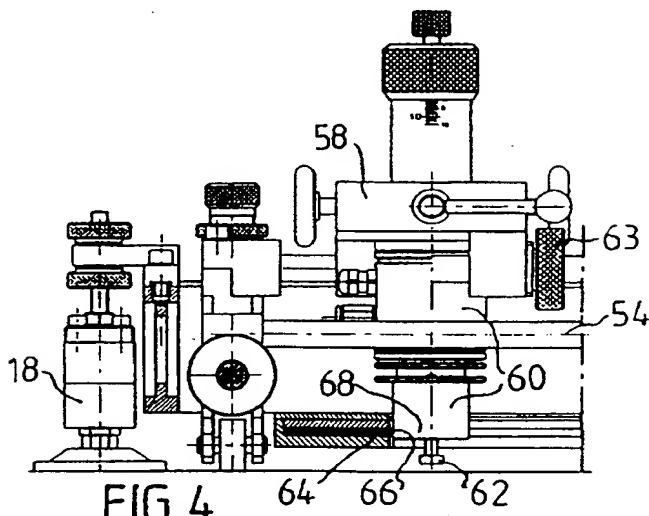


FIG. 4

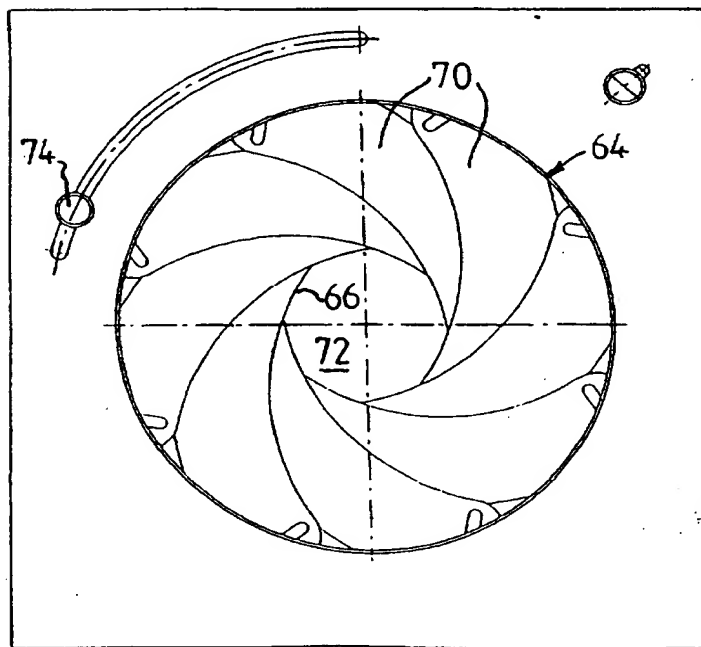


FIG. 5

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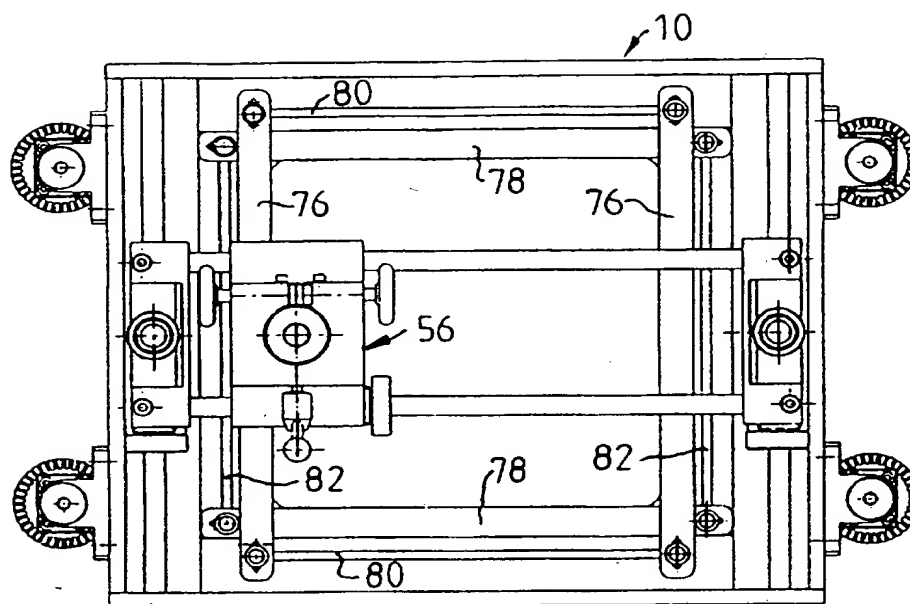


FIG. 6

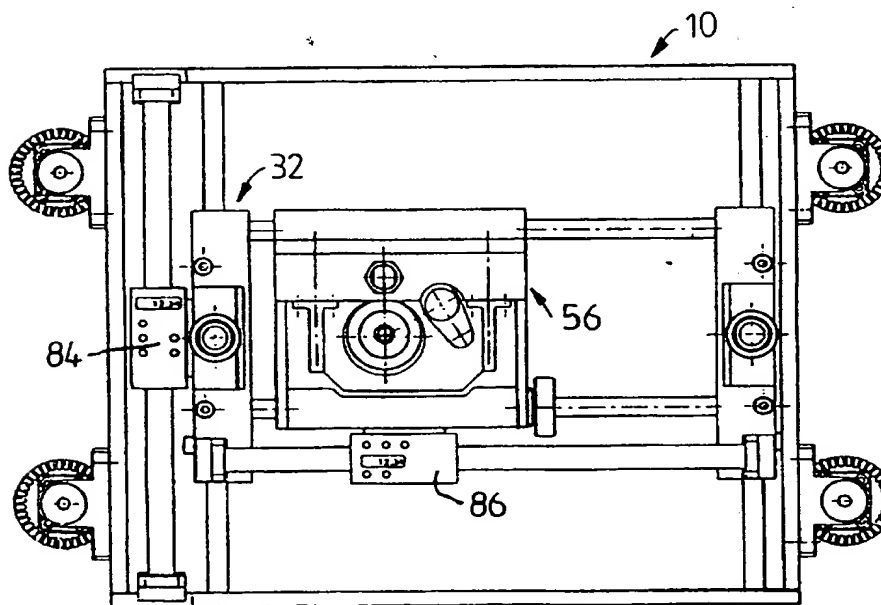


FIG. 7

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# INTERNATIONAL SEARCH REPORT

1

International application No.

PCT/SE 97/00164

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B64F 5/00, B23K 7/10, B23Q 1/62

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B23K, B23Q, B64F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPIL

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 4433926 A1 (HEINRICH SCHLICK GMBH), 2 November 1995 (02.11.95) --	
A	US 4383870 A (CREECH), 17 May 1983 (17.05.83) --	
A	US 4755232 A (THÖNES ET AL), 5 July 1988 (05.07.88) --	
A	SE 351148 B (AB GÖTAVERKEN), 20 June 1972 (20.06.72) --	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

9 June 1997

Date of mailing of the international search report

10 -06- 1997

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International application No.

PCT/SE 97/00164

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